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Risk Mitigation in Well Placement through Integrated Seismic Inversion Analysis in West Mumbai High, India

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Summary

3D seismic inversion in integration with petro-physical properties has been qualitatively and quantitatively used in reservoir characterization of Miocene Carbonate reservoir (L-III) in west part of Mumbai High, situated in western offshore of India, to reduce the uncertainties in placement of exploratory and development locations. L-III is the main producing reservoir in Mumbai High and more than a thousand exploratory and development wells have been drilled in whole of Mumbai High. Yet, proper placement of well locations is a challenge due to high heterogeneity in the area. The aim of study was to accurately define better porosity pods in L-III for proper placement of development and exploratory locations to avoid dry hole drilling. Seismic inversion was carried out over post stack PSTM data. Top of reservoir and other horizons were accurately correlated using impedance data. Petro physical study was carried out by cross plotting different reservoir parameters with well impedance and inverted impedance volume was calibrated with reservoir parameters. Since effective porosity in this area does not show linear relationship with impedance, Multi Attribute Analysis was not successful in computing porosity. Porosity volume was computed by acoustic impedance using Neural Network algorithm with EMERGE and was used to find out distribution of porosity in the area. Study was used in refinement of placement of exploratory locations and development locations from the new Platform.

Keywords*: Post-Stack Inversion, Mumbai Offshore*

Introduction

Reservoir characterization requires building a spatial model of the reservoir by using appropriate data gathered from different studies. Porosity and permeability are the most important parameters of reservoir and have the largest impact on reserves and production forecasts. However. to determine these properties in subsurface is very difficult. The main problem arises in the presence of dispersed shale or when the reservoir rock exhibits several types of porosity. An accurate and reliable reservoir characterization study is indispensable in minimizing uncertainty and in deciding an accurate location as well as in reservoir management. Seismic inversion has been used for several decades in the petroleum industry, both for exploration and production purposes. During this period, seismic inversion methods have progressed from the initial recursive inversion method to the present plethora of methods and software packages available to transform band-limited seismic traces to impedance traces. Now a days, most of the research efforts in this field are focused in the inversion and interpretation of AVO from pre-stack data. However, post-stack data obtained from recorded P-waves are still widely used because of their ready availability and low time-consuming processing. Because wells in a reservoir field are often spaced at hundreds or even thousands of meters, the ultimate goal of a seismic inversion procedure in the context of reservoir characterization is to provide models not only of acoustic impedance but also of other relevant physical properties, such as effective porosity and water saturation etc. for the interwell regions. Such quantitative interpretations may sometimes require the use of other seismic attributes in addition to the traditional seismic reflection amplitudes. The application of seismic impedance data has also progressed from qualitative assessments of prospects to the quantitative description of reservoir properties necessary for reservoir characterization.

Notwithstanding emerging technologies and new methods developed, post stack seismic inversion still remains a

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powerful tool in defining reservoir if integrated judiciously with geological, petrophysical and production data.

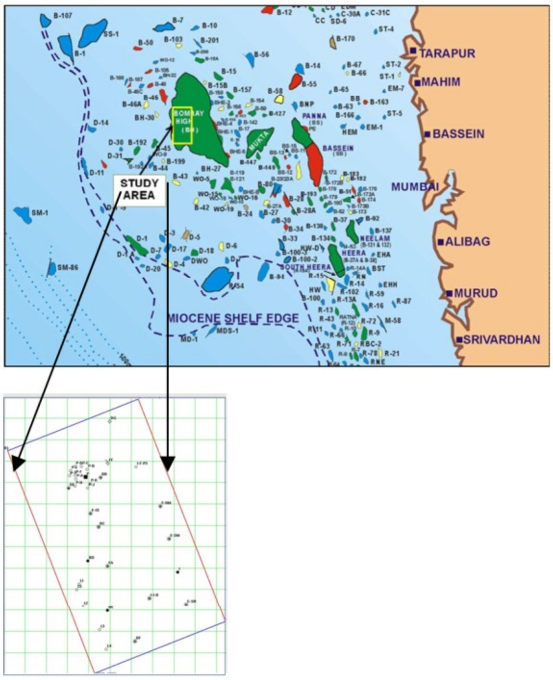

Fig.1: Location Map

The present study has been carried out in 500 sq. km of the western part of Mumbai High, in India, which is mature field and producing for more than three decades. Mumbai High is a doubly plunging asymmetric anticline structure, gently dipping westward and having sedimentary sequences of Tertiary age. Multi-layered thin Miocene carbonates of L-III unit, separated by thin shale layers, are the main producers. High reservoir heterogeneity is the main challenge of Mumbai High field. Heterogeneity may arise due to variation in porosity in carbonate layers affected by changes in clay content and other factors. Despite of more than 1200 wells drilled in the field, new well may come up with surprises. Therefore, proper placement of development locations is a big concern. Knowledge of layer wise distribution of porosity, along with structural disposition is very important. Study was carried out for proper placement of exploratory and development locations to be drilled from a new platform by analyzing post stack inversion data and estimating effective porosity using Neural Network method.

Methodology

Seismic Inversion:

Model based post stack seismic inversion was carried out using seismic 3D PSTM volume. Five horizons, corresponding to Litho-stratigraphic boundaries were correlated and used as geological constrains in preparing initial model. Horizons correlated on seismic data were refined by tracking over inverted impedance volume. Incorporating refined horizons, a new model was created and data was again inverted with the new model. Low frequency trend was extracted from nine vertical wells in the area having Sonic and Density logs. Synthetic seismograms from these well logs were correlated with seismic data at well locations. A good correlation, of the order of 80% to 85% was achieved.

The output inverted acoustic impedance volume has been able to resolve different reservoir layers vertically at all levels and describe horizontal variation in lithology and reservoir properties. Figures 2 shows vertical section of acoustic impedance through producing well BB with overlay of well P-Impedance showing calibration of computed impedance. Carbonate layers of thickness 6m to 10m are very well resolved. It has distinguished the producing layer at L-III level (Fig. 4). It has also indicated development of low impedance (may be due to fractures) in Basement, where it is producing. Figure 6 gives lateral variation of impedances at L-III level.

As a next step in the reservoir characterization process, acoustic impedance was sought to be calibrated with reservoir properties from Petrophysics. To this end, cross plots between impedance values at L-III and Basal clastic/Basement levels with gamma ray were studied for all the wells in the area. Cross plots were used for separating carbonates and shales and to differentiate porous carbonates from tight carbonates (Fig. 5). Pimpedance values were calibrated with petrophysical parameters of producing wells at well locations.

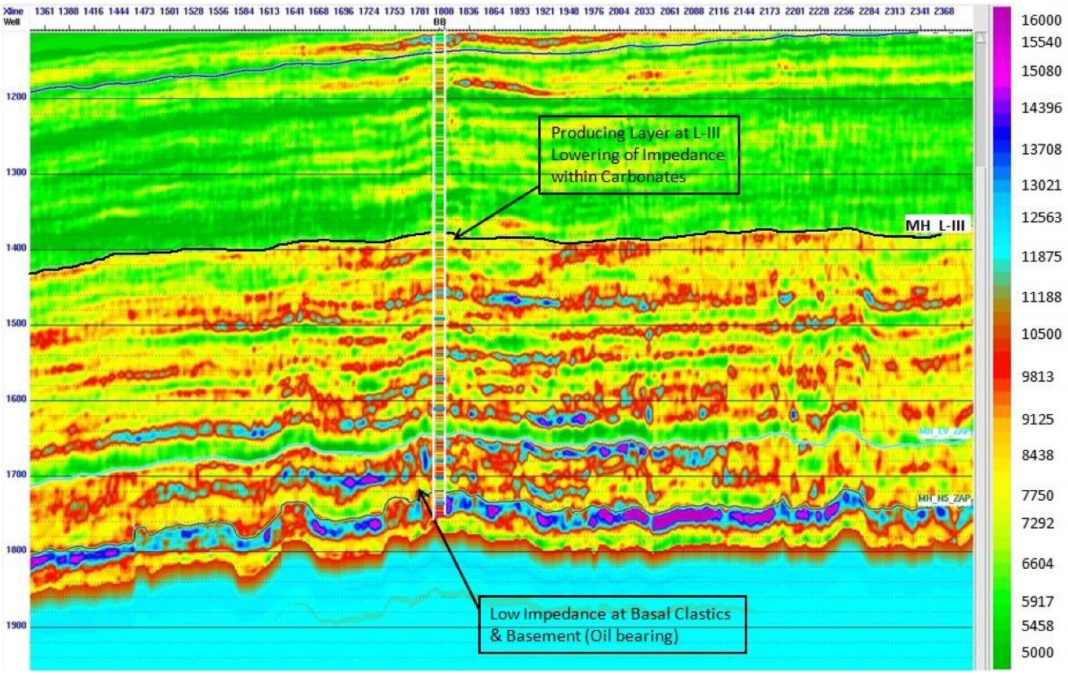

Fig.2: Acoustic Impedance section through a well BB. Overlay of P-Impedance log from the well on the computed impedance shows good correlation between two. Reservoir layers at L-III & Basal Clastics levels are very well resolved

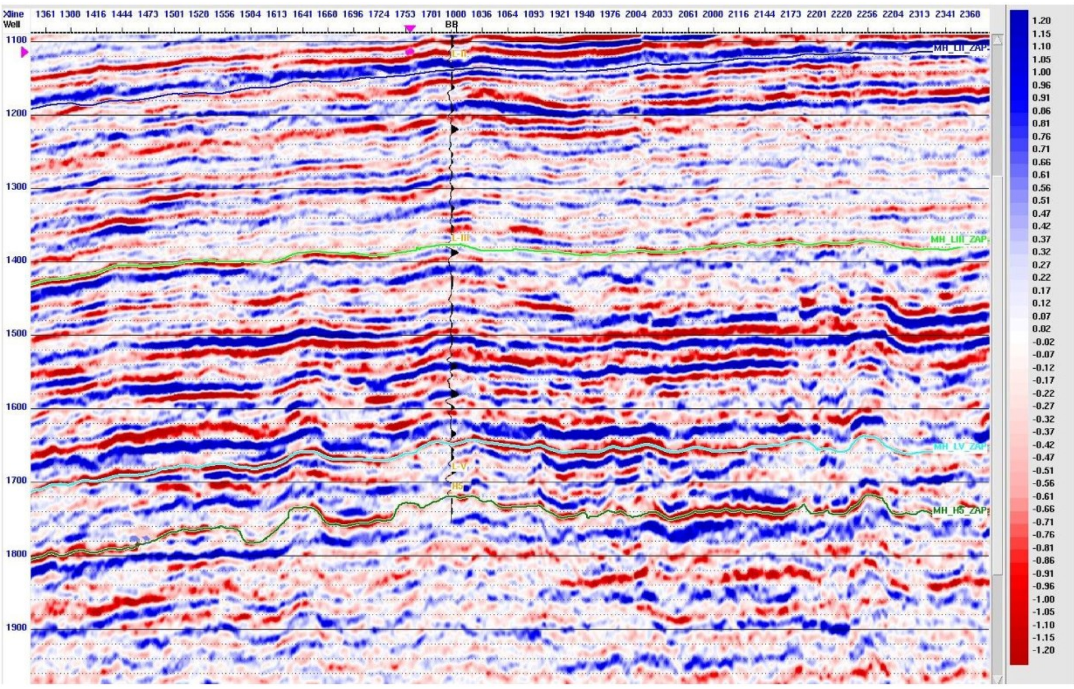

Fig.3: Seismic section through well BB with overlay of Synthetic Trace showing well to seismic tie at well location.

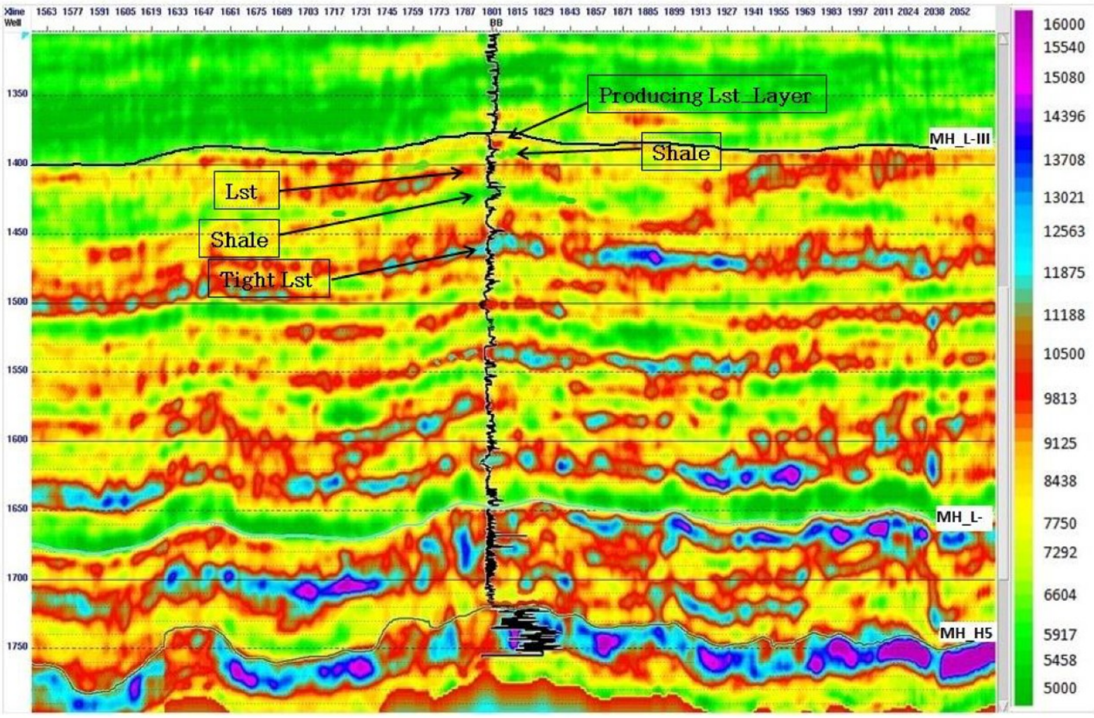

Fig.4: Zoomed Acoustic Impedance section through a well BB with overlay of Gamma Ray log, showing alternations of carbonate and shale layers.

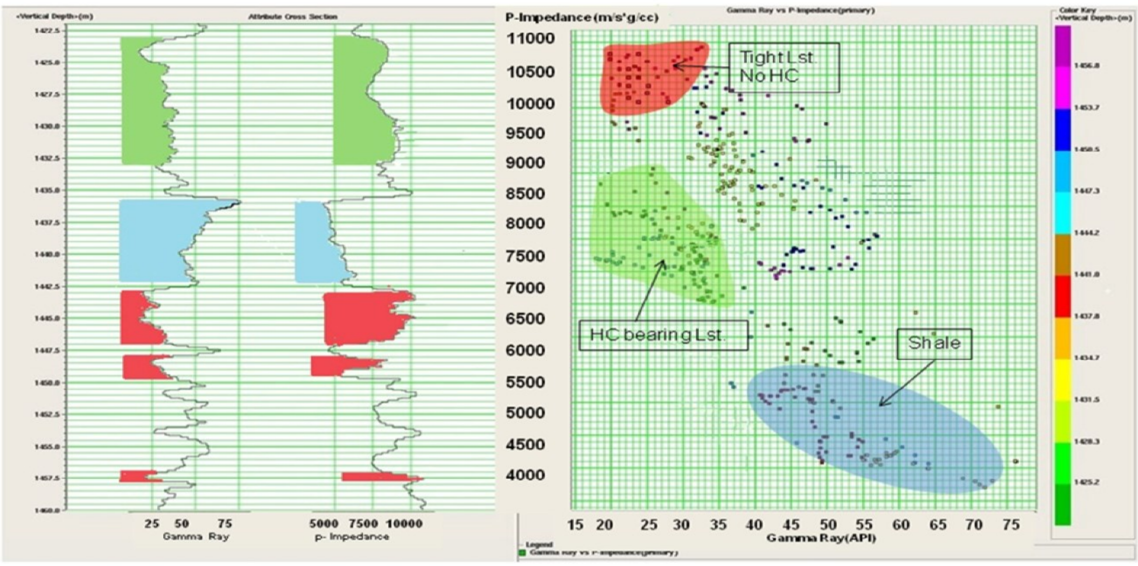

Fig.5: Cross Plot between Gamma Ray & Acoustic Impedance differentiating Hydro Carbon bearing Lst from tight Lst without Hydro Carbon.

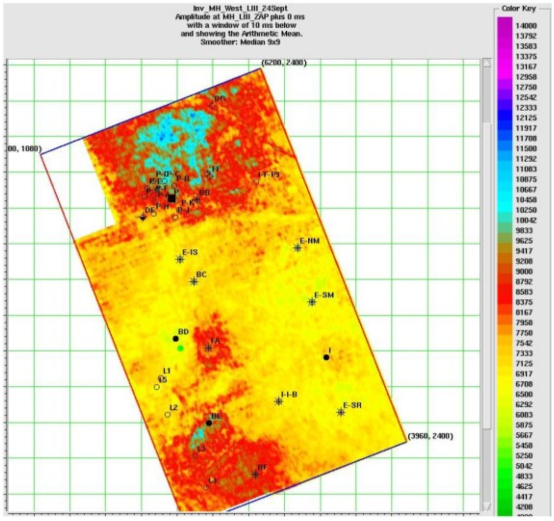

Fig.6: Variation in Av. Acoustic Impedance at L-III level

Estimation of Porosity

Effective porosity is one of the governing factor for finding and producing hydrocarbon. Hence, accurate estimation of effective porosity is most important factor in deciding the proper location to be drilled for exploration and development. Porosity evaluation from seismic data is a very important tool because it permits the definition of porosity distribution even far from drilled wells, allows a better characterization of known reservoirs in their economical and technical aspects, and provides much more information than does normal seismic processing in the search for new hydrocarbon fields. Yet, estimating accurate porosity away from wells is most challenging. Normally a linear relationship is assumed between acoustic impedance and porosity. In this case, we found that there is linear relationship between neutron porosity and acoustic impedance (Fig. 7). However, effective porosity does not always show linear relationship with impedance (Fig.8). Linear regression method could not be used in this case. To address this problem, Probabilistic Neural Network (PNN) technique was used. The neural network was used in an effort to account for non-linear relationship between effective porosity from logs and seismic, after first testing linear multi-attribute analysis method. Computation of porosity through PNN analysis was performed in the following steps:

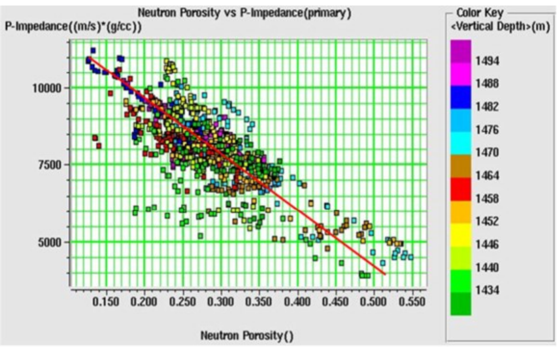

Fig.7: Cross plot between acoustic impedance and neutron porosity in one of the wells in the area shows linear relationship.

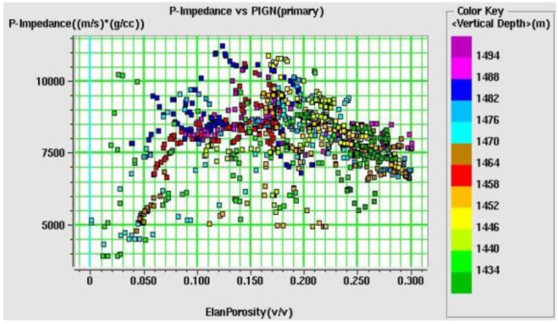

Fig.8: Cross plot between acoustic impedance and effective porosity (Ellan Processed) in one of the wells in the area, shows non-linear relationship.

1. Performing multi-attribute step-wise linear regression analysis using Ellan processed porosity logs from 14 wells and its validation by elimination method. Fig. 9 shows validation results by multi-attribute analysis. An average correlation of only 56% was obtained.
2. Training neural networks to establish the non-linear relationships between seismic attributes and effective porosity at well locations.
3. Applying trained neural network to 3-D seismic data volume to get a volume of computed porosity.
4. Validation results on wells by elimination method.Fig 10 shows validation results. A correlation of 85% with an average error of 3.54 was achieved.

Final porosity volume was further validated by comparing it with actual porosity logs at well locations Fig. 11 shows a porosity section through well BB with porosity log inserted at well location. A very good correlation can be observed between the two, assuring the confidence in estimated porosity.

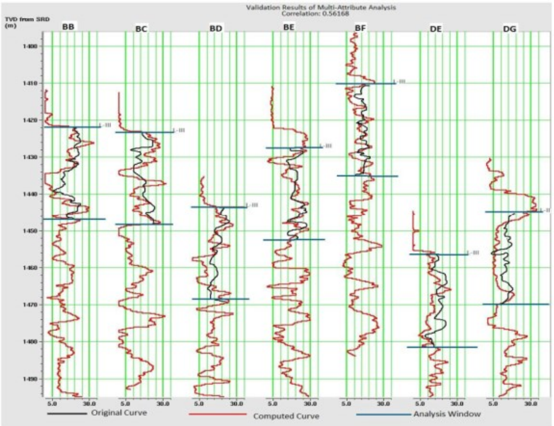

Fig.9: Validation of Multi-Attribute Analysis at well locations. 56% correlation between actual log and estimated log.

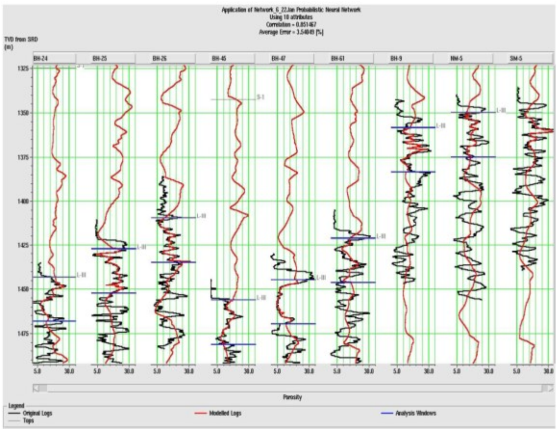

Fig.10: Validation of Neural Networks at well locations. 85% correlation between actual logs and estimated logs.

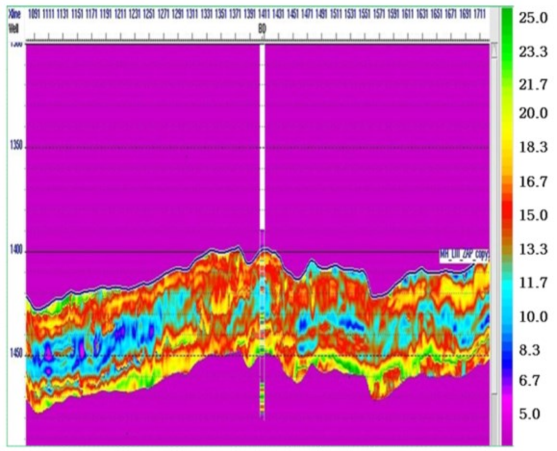

Fig.11: A section from computed porosity volume with actual log inserted at well location. Good correlation between two verifies the accuracy of computed porosity volume.

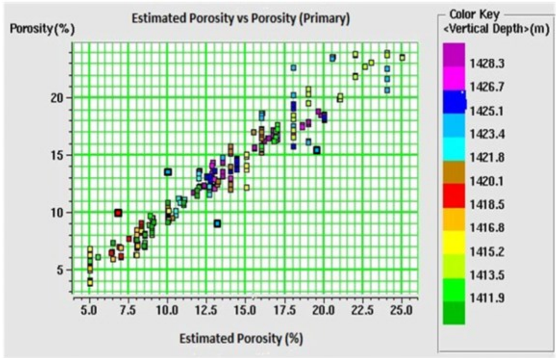

Fig.12: Cross plot between Estimated Porosity and Actual Porosity at well FF validates the accuracy of the results

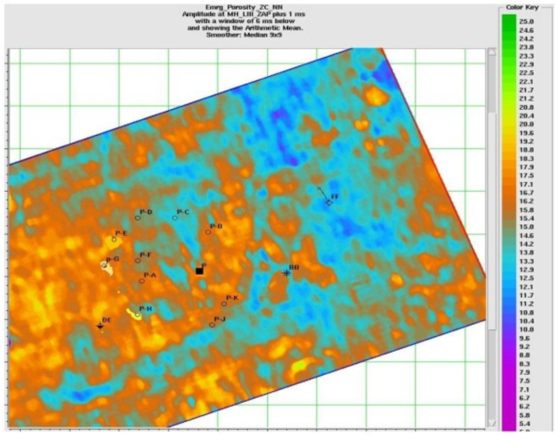

Fig.13: (Left) Porosity distribution at L-III level. Blue colour represents low porosity zones to be avoided for drilling. Moderate to high porosity zones in yellow colour recommended for development locations, if structurally favourable.

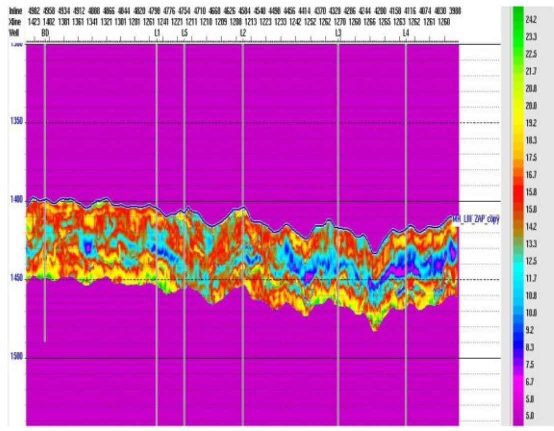

Fig.14: Porosity section through exploratory locations placed on the basis of this study

Results and Conclusions

Acoustic impedance in corroboration with petrophysical data has been successful in resolving reservoir and nonreservoir layers.

Derived porosity volume shows strong correlation with logs suggesting that porosity can be accurately estimated by Probabilistic Neural Network.

In this part of Mumbai High,with high heterogeneity in reservoir properties, PNN gives better estimation of porosity than Multi-Attribute Analysis as PNN can address non-linear relationship between porosity and seismic attributes.

Acoustic impedance calibrated with petrophysical data and computed porosity were used in accurate placement of exploratory and development locations (Fig. 13 &14).

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